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**CHEMISTRY
 HIGHER LEVEL
 PAPER 3**

Candidate session number

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Wednesday 19 November 2014 (morning)

Examination code

1 hour 15 minutes

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **Chemistry Data Booklet** is required for this paper.
- The maximum mark for this examination paper is [50 marks].

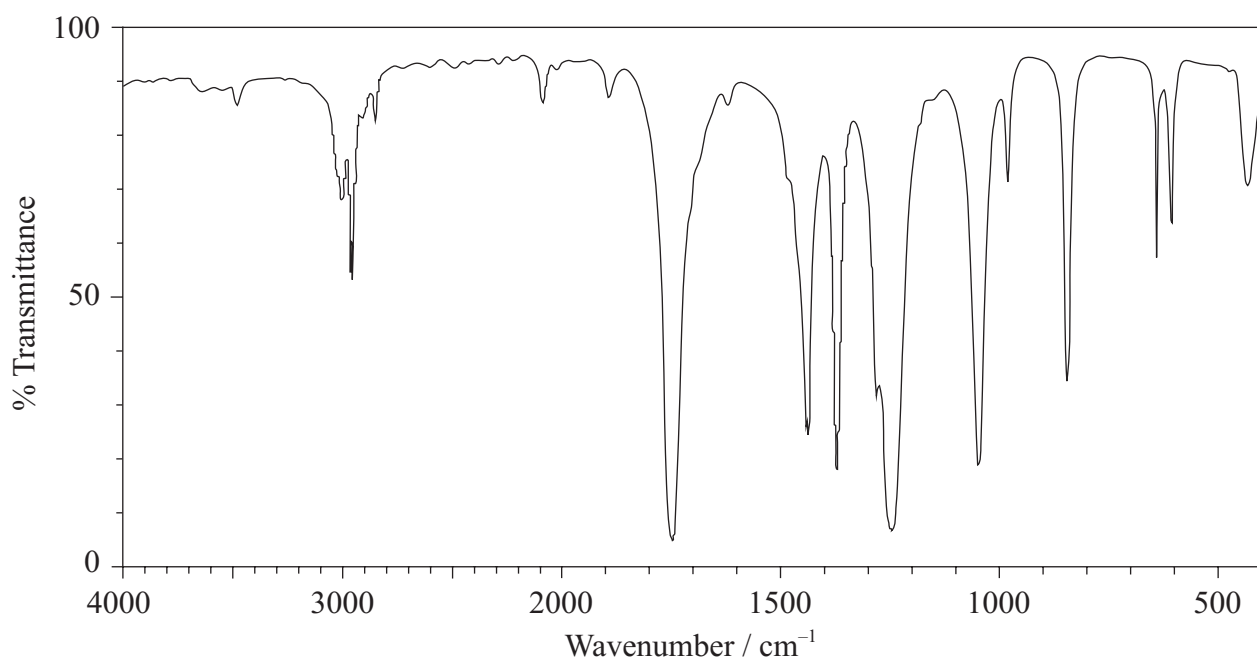
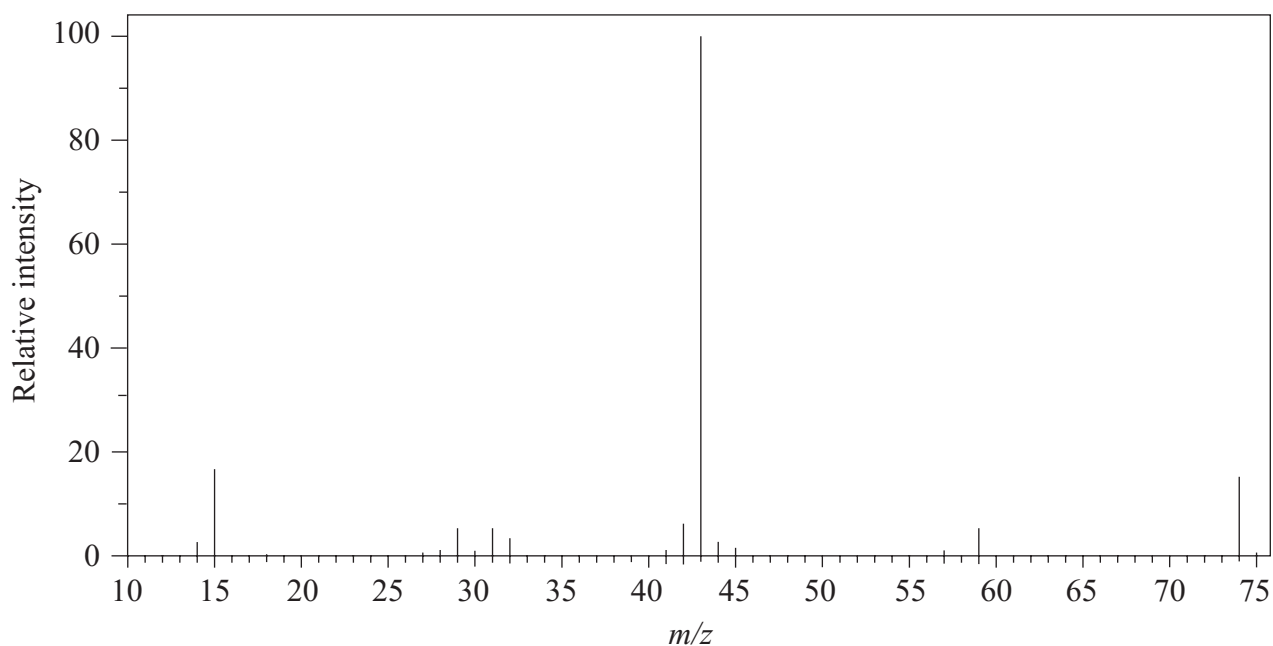
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40EP01

Option A — Modern analytical chemistry

1. The mass spectrum and infrared (IR) spectrum of a compound are shown below.



[Source: SDBS web: www.sdb.srioddb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2013)]

(Option A continues on the following page)



(Option A, question 1 continued)

- (a) (i) State the information about this particular compound that can be derived from the mass spectrum and outline how it is found. [2]

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- (ii) Suggest how the fragment with $m/z = 43$ is formed from the original molecule. [1]

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- (b) (i) Use the IR spectrum in the region $1600 - 1800 \text{ cm}^{-1}$ to deduce **one** functional group that is present in the compound and **one** group that is absent. [2]

Present:

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Absent:

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.....

(Option A continues on the following page)



(Option A, question 1 continued)

- (ii) The molecular formula of the compound is $\text{C}_3\text{H}_6\text{O}_2$. Explain, with reference to another region of the IR spectrum, why the compound could **not** be propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$. [2]

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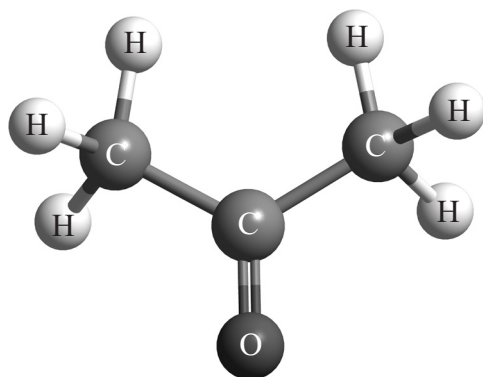
- (iii) Deduce the structures of two possible isomers of propanoic acid consistent with the IR spectrum. [2]

(Option A continues on the following page)

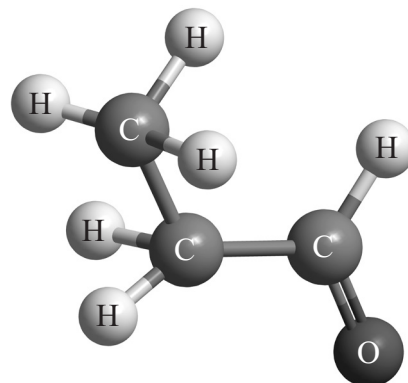


(Option A, question 1 continued)

- (c) ^1H NMR spectroscopy is often very useful in distinguishing between closely related compounds such as the ones shown below.



Compound I



Compound II

Deduce the ^1H NMR spectra you would expect for each compound and complete the table below. (The answers for propanoic acid are given as a guide.)

[5]

Note that some of the boxes may be blank.

Compound	Number of peaks	Chemical shift range / ppm	Area	Splitting pattern
Propanoic acid	3	0.9 – 1.0	3	triplet
		2.0 – 2.5	2	quartet
		9.0 – 13.0	1	singlet
Compound I				
Compound II				

(Option A continues on the following page)



(Option A continued)

2. Waste water from an abandoned copper mine is suspected of polluting a community's drinking water supply, causing concern that the concentration of dissolved copper compounds might exceed the legal limit of 1.3 ppm.

- (a) State the most appropriate analytical technique to investigate the concentration of copper in the water supply. [1]

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- (b) Outline how this technique could be used to determine the concentration of copper ions present in a particular sample of water. [2]

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- (c) The concentration of transition metal ions can also be determined by measuring the colour intensity of solutions of their complex ions. In the case of copper(II) ions, excess aqueous ammonia is sometimes added before measuring the absorption.

- (i) Describe why adding excess ammonia to aqueous copper(II) ions causes the shade of the blue colour to change. [4]

.....

(Option A continues on the following page)



(Option A, question 2 continued)

- (ii) State **one** other factor, apart from a change of ligand, which could affect the colour of a transition metal complex. [1]

.....

3. The principles of chromatography can be demonstrated using paper chromatography to analyse the ink of a pen, using propanone as the mobile phase.

- (a) Explain how paper chromatography separates the components. [2]

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- (b) State **one** factor that would alter the R_f value of a particular component. [1]

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End of Option A



Option B — Human biochemistry

4. (a) Define the term *iodine number*. [1]

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- (b) Diets that are high in omega-3 fatty acids are recommended as healthy for the heart. Eicosapentaenoic acid ($M_r=302$) is a common omega-3 fatty acid found in fish oils. Calculate the number of carbon-carbon double bonds in one molecule of this acid if 3.02 g of acid reacts with 12.7 g of I_2 ($M_r=254$). [3]

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5. Compare the structures and chemical formulas of the two essential fatty acids linoleic acid and linolenic acid. [4]

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(Option B continues on the following page)



(Option B continued)

6. (a) (i) Using Table 19 of the Data Booklet, draw the structure of the **two** dipeptides formed by the reaction of glycine with valine. [2]

- (ii) State the other product of the reaction in (i). [1]

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- (b) Explain how a given protein can be broken down into its constituent amino acids and how these can be identified by electrophoresis. [5]

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(Option B continues on the following page)



(Option B continued)

7. (a) Describe how genetic information is encoded within the double helical structure of DNA. [3]

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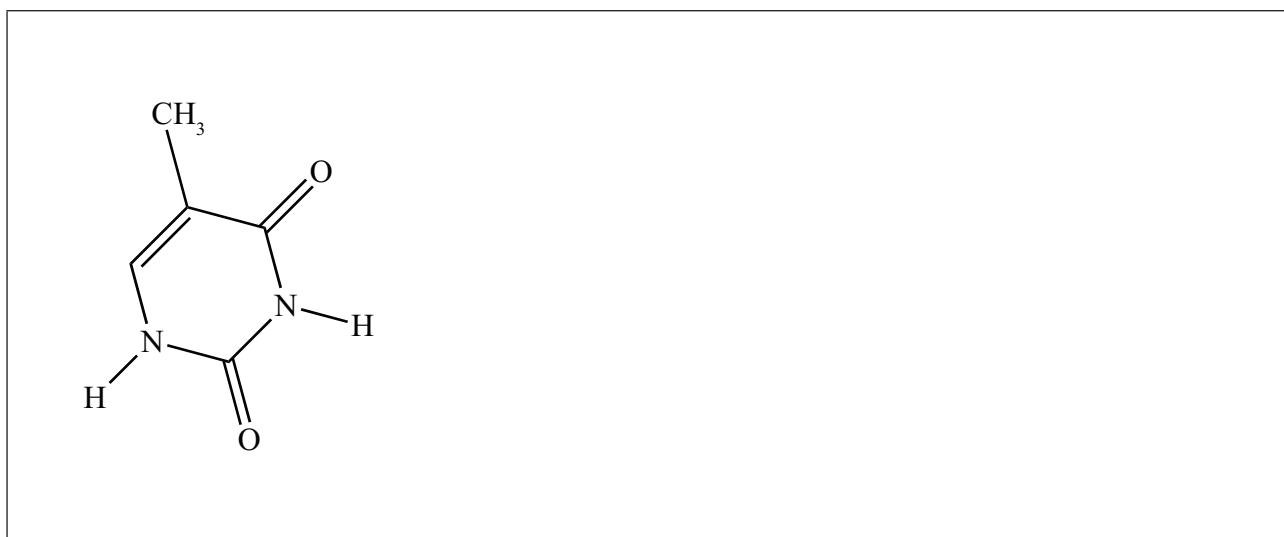
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- (b) State the name of the bond between complementary base pairs of DNA. [1]

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- (c) Explain the bonding between base pairs by drawing the complementary base next to thymine below and by showing the bonds that hold the pairs of bases together. Use the structures given in Table 21 of the Data Booklet. [3]



(Option B continues on the following page)



(Option B continued)

8. Describe **three** characteristics of enzymes.

[2]

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End of Option B

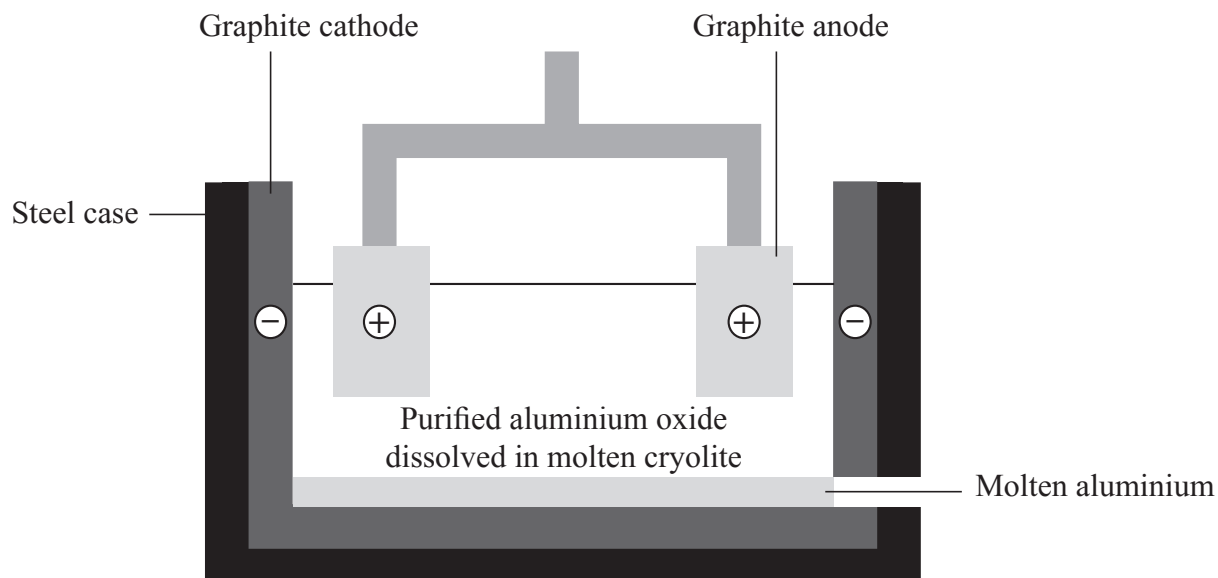


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Turn over

Option C — Chemistry in industry and technology

9. Aluminium is chemically reactive so it has to be extracted by the electrolysis of aluminium oxide dissolved in molten cryolite.



- (a) (i) Suggest why the aluminium oxide is dissolved in molten cryolite.

[1]

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(Option C continues on the following page)



(Option C, question 9 continued)

- (ii) Deduce an equation for the discharge of the ions at each electrode. [2]

Positive electrode (anode):

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Negative electrode (cathode):

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- (iii) Suggest why the anodes have to be replaced at regular intervals. [1]

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(Option C continues on the following page)



(Option C, question 9 continued)

- (b) (i) Outline why aluminium is alloyed with copper and magnesium when used to construct aircraft bodies. [1]

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- (ii) State **two** properties of aluminium that make it suitable for use in overhead power cables. [1]

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- (c) Discuss **two** environmental impacts of the chlor-alkali industry. [2]

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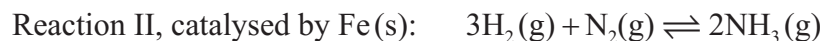
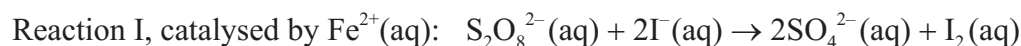
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(Option C continues on the following page)



(Option C continued)

10. Iron acts as a catalyst in the chemical reactions below.



Outline the mechanism by which each catalyst lowers the activation energy in the reactions above, and state a particular disadvantage of each type of catalysis.

[4]

Catalyst	Mechanism	Disadvantage
$\text{Fe}^{2+}(\text{aq})$	<p>.....</p> <p>.....</p>	<p>.....</p> <p>.....</p>
$\text{Fe}(\text{s})$	<p>.....</p> <p>.....</p>	<p>.....</p> <p>.....</p>

11. The photovoltaic cell is a valuable source of energy. Describe its construction and how it responds to sunlight.

[4]

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(Option C continues on the following page)



(Option C continued)

12. Liquid crystals are widely used in displays.

(a) Describe the meaning of the term liquid crystals.

[1]

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(b) When a liquid-crystal display is warmed with a hairdryer, the display loses its clarity and may no longer be visible. Explain why this happens on a molecular level.

[2]

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(Option C continues on the following page)



(Option C, question 12 continued)

- (c) Discuss aspects of the structure of Kevlar[®] that allow it to be used for both bullet-proof jackets and liquid crystals. [2]

Bullet-proof jackets:

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Liquid crystal:

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(Option C continues on the following page)



(Option C continued)

13. There is much debate about the need for laws to regulate research and development into nanotechnology.

(a) Define the term *nanotechnology*.

[2]

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(b) Discuss **two** concerns about its development and use.

[2]

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End of Option C



Option D — Medicines and drugs

14. The development of new and improved medications for the reduction and management of pain is an important part of 21st-century medicine.

- (a) Discuss **two** advantages and **two** disadvantages of the medical use of morphine and its derivatives.

[2]

Advantages:

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Disadvantages:

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- (b) Explain the increased potency of diamorphine (heroin) compared to morphine.

[2]

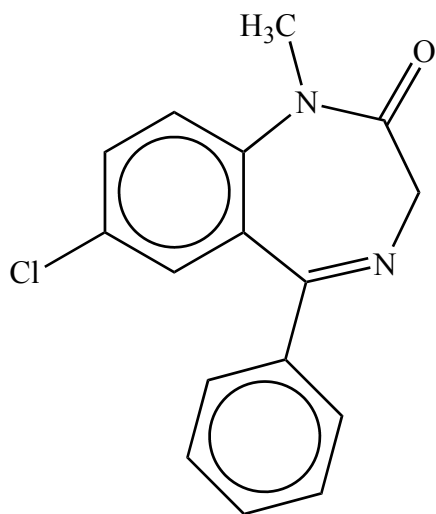
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(Option D continues on the following page)

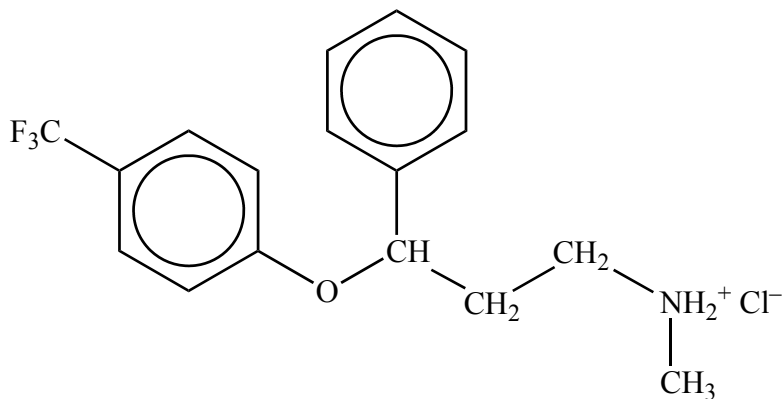


(Option D continued)

15. Compare the structures of diazepam (Valium®) and fluoxetine hydrochloride (Prozac®). [2]



Diazepam (Valium®)



Fluoxetine hydrochloride (Prozac®)

One similarity:

.....

One difference:

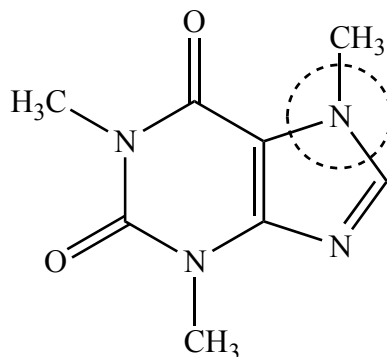
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(Option D continues on the following page)



(Option D continued)

16. (a) Caffeine is commonly used as a stimulant. State the name of the functional group circled in the structure below. [1]



Caffeine

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- (b) State **two** side-effects of caffeine consumption on the body. [1]

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(Option D continues on the following page)



(Option D continued)

17. The first commercially available antibiotic came from a class of compounds known as the penicillins.

- (a) Outline the role played by Florey and Chain in the development of penicillin. [2]

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- (b) Explain how penicillins work and why it is necessary to continually modify the side-chain. [3]

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- (c) Explain the importance of the beta-lactam ring in the action of penicillin. [3]

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(Option D continues on the following page)



(Option D continued)

18. (a) State **two** ways in which viruses are different from bacteria. [2]

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- (b) Describe **two** ways in which antiviral drugs work. [2]

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- (c) Discuss **three** of the difficulties associated with solving the AIDS problem. [3]

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19. Describe how computers are used in drug design. [2]

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End of Option D



Option E — Environmental chemistry

20. (a) Nitrogen oxides, NO_x , are known air pollutants. State **one** natural and **one** anthropogenic source of NO_x . [2]

Natural source:

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Anthropogenic source:

.....

- (b) State **one** form of pollution produced as a result of excess NO_x in the atmosphere. [1]

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- (c) State **one** method to decrease the presence of NO_x in the atmosphere. [1]

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(Option E continues on the following page)



(Option E continued)

21. (a) Describe how the greenhouse effect causes the atmosphere of the Earth to increase in temperature. [3]

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- (b) Identify **one** greenhouse gas other than CO₂ and H₂O and suggest a significant source. [2]

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(Option E continues on the following page)



(Option E continued)

- 22.** The ozone layer protects us by absorbing ultraviolet (UV) radiation from the Sun during its natural formation and depletion.

- (a) Explain how the bonding in O_2 and O_3 affects the wavelengths of UV light they absorb. [3]

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- (b) The chemical balance of the stratosphere is disrupted by the presence of chlorofluorocarbons (CFCs) and other ozone-depleting compounds. Describe, using equations, how CFCs contribute to ozone depletion. [3]

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(Option E continues on the following page)



(Option E continued)

23. The availability of clean water is an important resource for communities. When natural fresh-water sources are unavailable alternative solutions must be considered. Explain how multi-stage distillation and reverse osmosis can be used to obtain fresh water and suggest **one** disadvantage for each process.

[6]

Multi-stage distillation:

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Osmosis:

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24. (a) In an acidic soil, nitrate ions may undergo reduction to form ammonium ions. Deduce a half-equation for the reaction.

[3]

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- (b) State **one** disadvantage of this reaction for plant nutrition.

[1]

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End of Option E



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Turn over

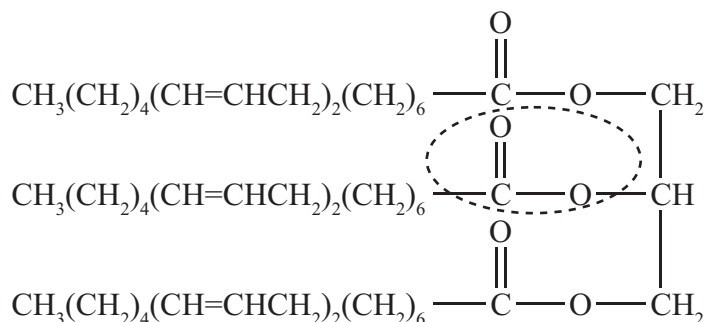
Option F — Food chemistry

25. Most foods contain nutrients.

- (a) Lipids, minerals and water are examples of nutrients. State **two** other examples and a food source for each. [2]

Nutrient	Food source
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- (b) Triglycerides are formed by the reaction of propane-1,2,3-triol (glycerol) with fatty acids.



- (i) State the name of the functional group circled in the triglyceride. [1]

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- (ii) Identify the other product of the reaction. [1]

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(Option F continues on the following page)



(Option F, question 25 continued)

- (c) (i) State the difference in structure between the fatty acids found in an oil and those in a fat. [1]

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- (ii) Comment on the relative stability of oils and fats and state the names of **two** possible types of degradation reaction. [2]

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26. Most packaged foods have an expiry (best before) date printed on the packet giving an indication of the product's shelf life.

- (a) (i) Explain the meaning of the term shelf life. [2]

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- (ii) Identify **one** factor that changes the shelf life and how it affects the quality of foods. [2]

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(Option F continues on the following page)



(Option F, question 26 continued)

- (b) Oxidative rancidity of oils begins with the removal of hydrogen atoms in close proximity to the C=C bonds and can be represented as:



- (i) State the essential condition for this initiation step. [1]

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- (ii) Outline the remaining steps in the mechanism using appropriate equations. [3]

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- (c) Explain how antioxidants affect the process of photo-oxidation. [2]

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(Option F continues on the following page)



(Option F continued)

27. Foods contain pigments.

- (a) Red meat contains the colourant heme, the oxidation of which causes the meat to become discoloured.

- (i) Outline the oxidation processes that occur.

[3]

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- (ii) Other than by using additives, state **one** way in which oxidation can be minimized.

[1]

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(Option F continues on the following page)



(Option F, question 27 continued)

- (b) Compare the structures of heme B and chlorophyll a, giving **two** similarities and **two** differences. Use Table 22 of the Data Booklet. [4]

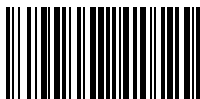
Two similarities:

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Two differences:

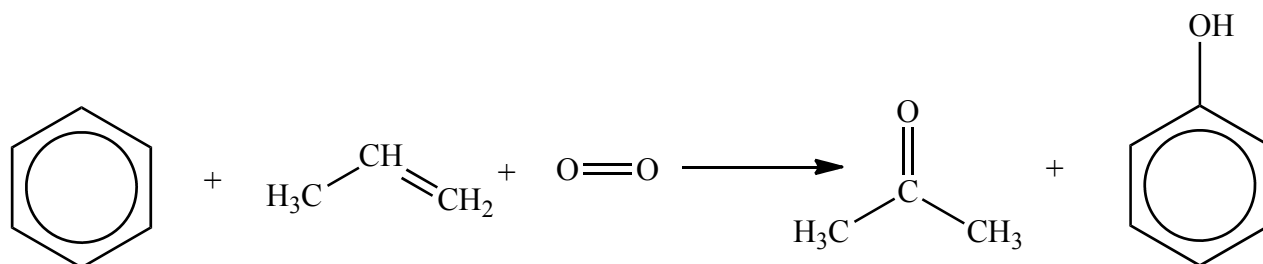
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End of Option F



Option G — Further organic chemistry

28. The cumene process is used for the production of both propanone and phenol. The overall reaction is shown in the equation below.



This process is important in the polymer industry. Propanone can be converted into methyl methacrylate, the monomer used to make Perspex[®], and phenol is used in phenol-methanal resins, which are important thermosetting plastics.

- (a) (i) Like alcohols and carboxylic acids, phenols contain a hydroxyl (O–H) group. List these three classes of compounds in order of **increasing** acidity of the hydroxyl group. [1]

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- (ii) State and explain how the presence of a halogen substituent might affect the acidity of carboxylic acids. [3]

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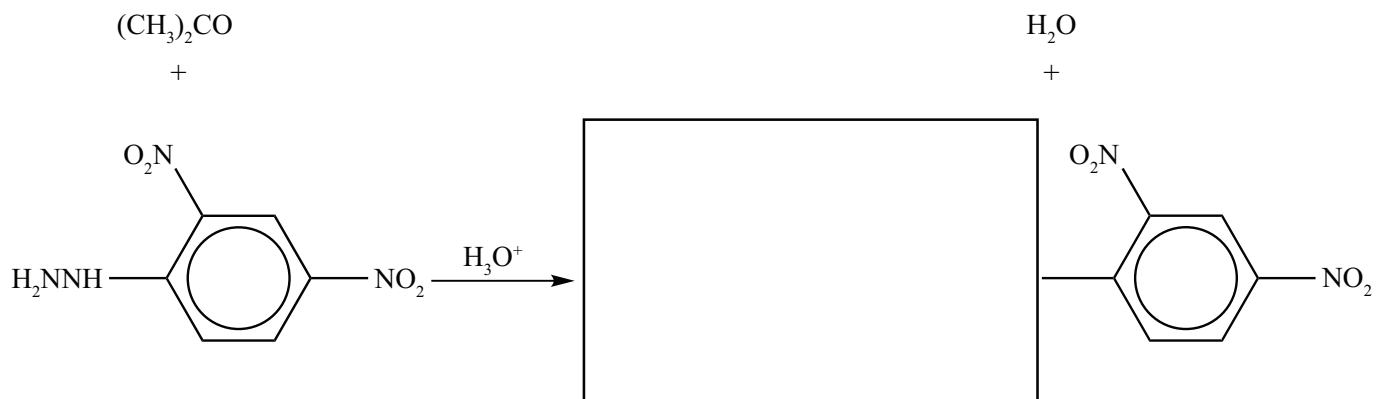
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(Option G continues on the following page)



(Option G, question 28 continued)

- (b) (i) Propanone and other carbonyl compounds react with 2,4-dinitrophenylhydrazine.



Complete the equation above by drawing the rest of the structure of the organic product.

[1]

- (ii) State what would be observed when the reaction occurs.

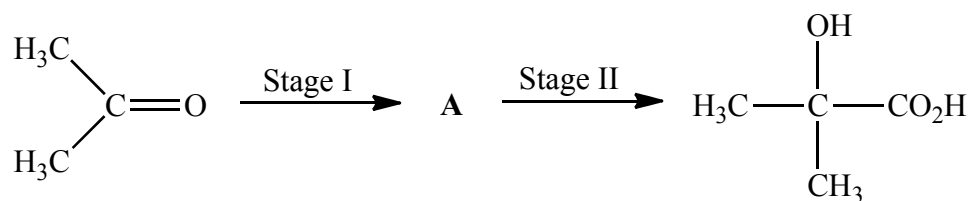
[1]

(Option G continues on the following page)



(Option G, question 28 continued)

- (c) To produce methyl methacrylate, propanone must first be converted into 2-hydroxy-2-methylpropanoic acid, as shown in the scheme below.



- (i) State the structure of the intermediate **A** and the reagents for both its formation from propanone and its conversion to the final product. [3]

Structure of **A**:

Reagent to form **A**:

.....

Reagent for converting **A** to the final product:

.....

(Option G continues on the following page)



(Option G, question 28 continued)

- (ii) 2-hydroxy-2-methylpropanoic acid is dehydrated, by heating with phosphoric acid, to produce methacrylic acid ($\text{CH}_2=\text{C}(\text{CH}_3)\text{COOH}$), which is esterified with methanol to give the methyl methacrylate monomer. Explain the mechanism of the dehydration reaction. [4]

- (d) Propanone could also be formed from propene by reaction with steam over an acidic catalyst, followed by oxidation of the product.

The reaction of propene with water can yield two possible products. Explain, in terms of the stability of the intermediate carbocations, why one is formed in much greater quantities than the other. [3]

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(Option G continues on the following page)



(Option G continued)

29. Functional groups often display different behaviour when they are connected to a benzene ring.

- (a) (i) The halogen atoms in chlorobenzene, $\text{C}_6\text{H}_5\text{Cl}$, and (chloromethyl)benzene, $\text{C}_6\text{H}_5\text{CH}_2\text{Cl}$, differ in the rate at which they are substituted by reaction with aqueous sodium hydroxide. List these two compounds in order of increasing reaction rate. [1]

Least reactive	<div style="display: flex; align-items: center; justify-content: center;"> <div style="flex-grow: 1; border-bottom: 1px solid black; position: relative;"> → </div> </div>	Most reactive
<div style="display: flex; justify-content: space-between; margin-top: 5px;"> </div>		

- (ii) Explain the difference in reactivity between chlorobenzene and (chloromethyl)benzene. [2]

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- (b) (i) Benzoyl chloride, $\text{C}_6\text{H}_5\text{COCl}$, reacts with both ethanol and benzene. State the types of reaction that occur and the class of compound to which each product belongs. [4]

Reactant	Reaction type	Class of product
Ethanol
Benzene

(Option G continues on the following page)



(Option G, question 29 continued)

- (ii) The reaction with benzene requires a catalyst. Identify a suitable catalyst and deduce the structure of the organic intermediate formed when benzoyl chloride reacts with this catalyst. [2]

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End of Option G



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